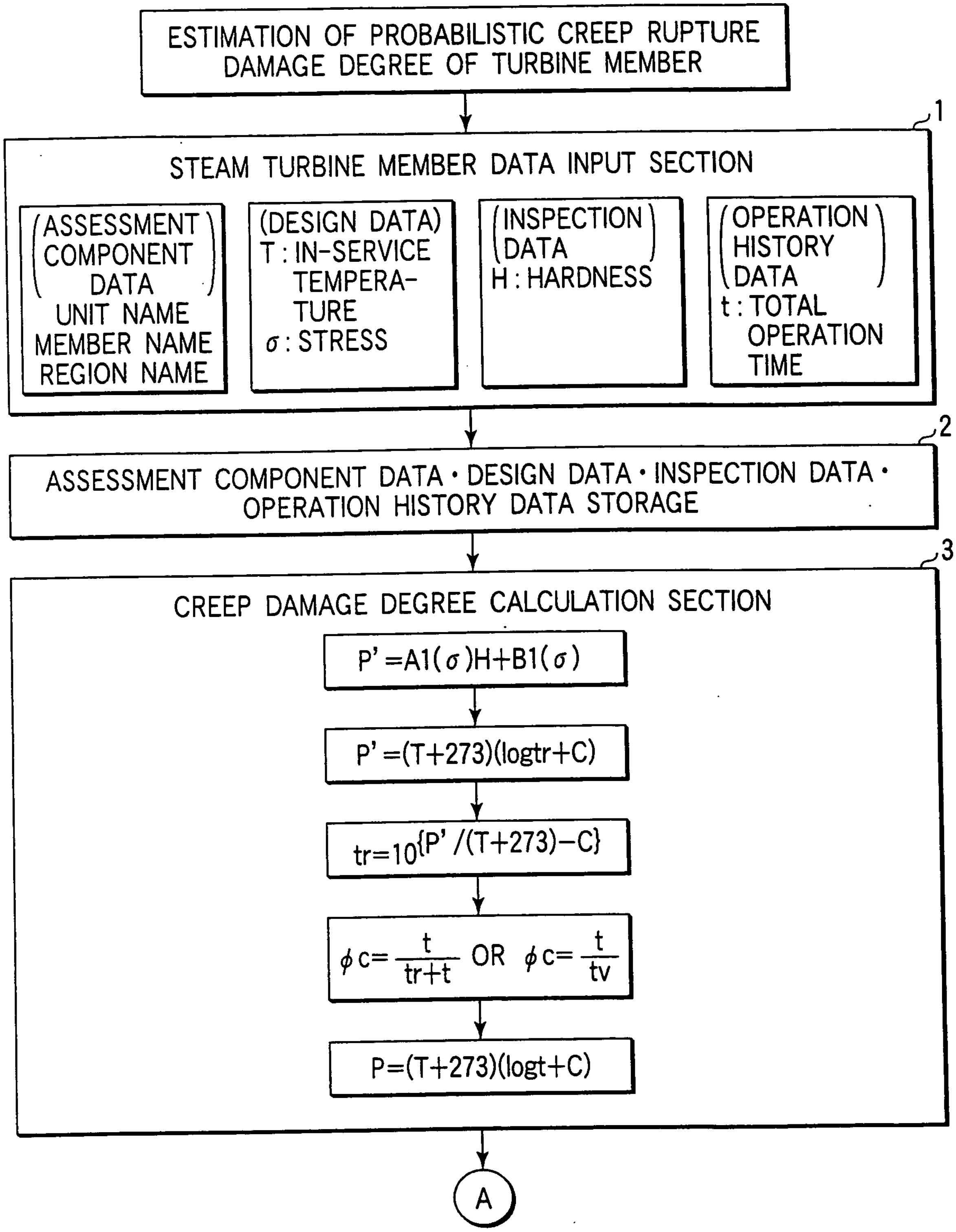
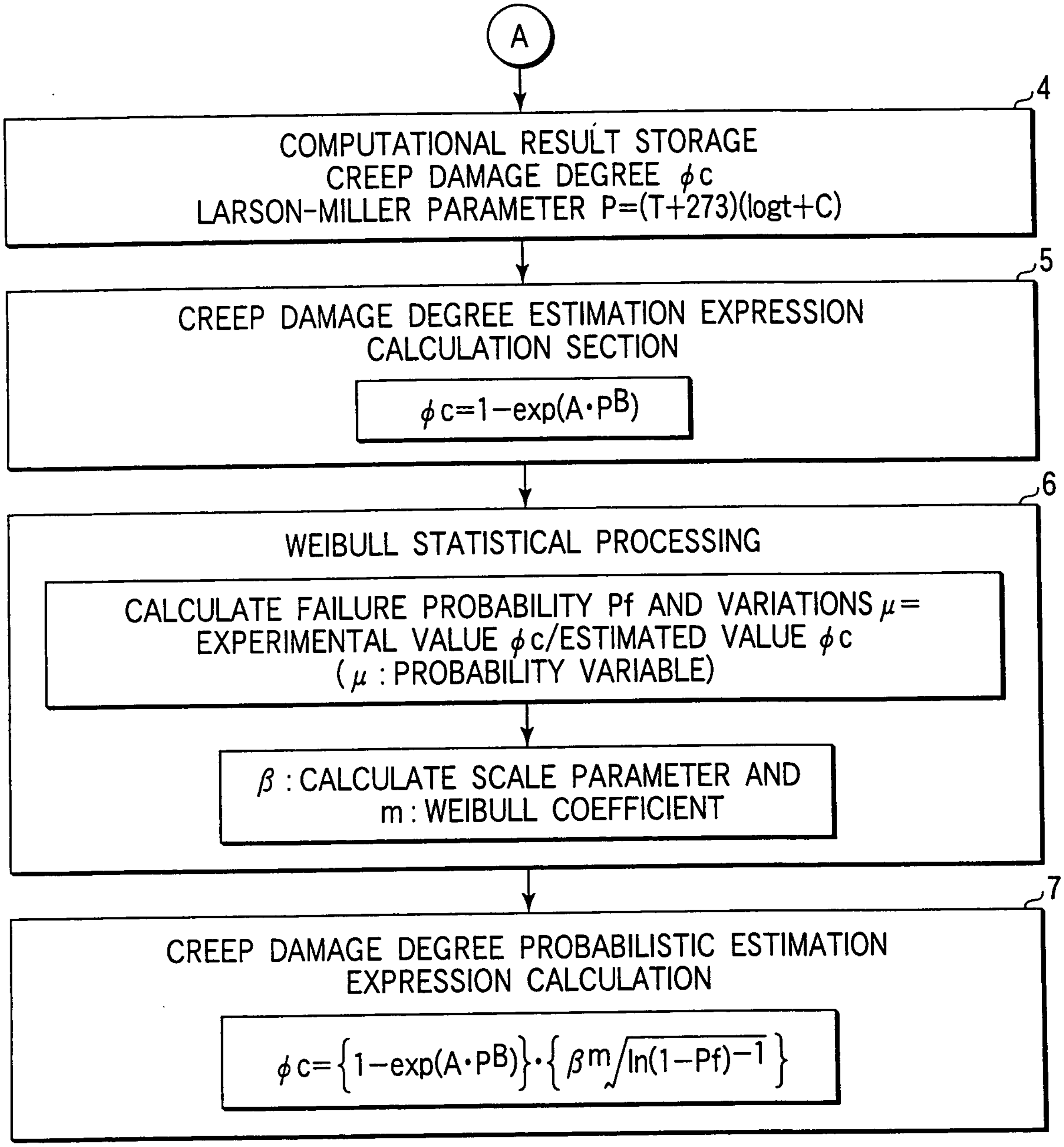

ESTIMATION OF PROBABILISTIC CREEP RUPTURE DAMAGE DEGREE OF TURBINE MEMBER
1
STEAM TURBINE MEMBER DATA INPUT SECTION
(ASSESSMENT COMPONENT DATA) UNIT NAME MEMBER NAME REGION NAME
(DESIGN DATA) T : IN-SERVICE TEMPERATURE σ : STRESS
(INSPECTION DATA) H : HARDNESS
(OPERATION HISTORY DATA) t : TOTAL OPERATION TIME
2
ASSESSMENT COMPONENT DATA • DESIGN DATA • INSPECTION DATA • OPERATION HISTORY DATA STORAGE
3
CREEP DAMAGE DEGREE CALCULATION SECTION
$P'=A1(\sigma)H+B1(\sigma)$
$P'=(T+273)(\log tr+C)$
$tr=10^{\{P'/(T+273)-C\}}$
$\phi c=\frac{t}{tr+t}$ OR $\phi c=\frac{t}{tv}$
$P=(T+273)(\log t+C)$
A

FIG. 1A


A
4
COMPUTATIONAL RESULT STORAGE
CREEP DAMAGE DEGREE ϕc
LARSON-MILLER PARAMETER $P=(T+273)(\log t+C)$
5
CREEP DAMAGE DEGREE ESTIMATION EXPRESSION CALCULATION SECTION
$\phi c=1-\exp(A\cdot P^{B})$
6
WEIBULL STATISTICAL PROCESSING
CALCULATE FAILURE PROBABILITY Pf AND VARIATIONS μ= EXPERIMENTAL VALUE ϕc/ESTIMATED VALUE ϕc
(μ : PROBABILITY VARIABLE)
β : CALCULATE SCALE PARAMETER AND
m : WEIBULL COEFFICIENT
7
CREEP DAMAGE DEGREE PROBABILISTIC ESTIMATION EXPRESSION CALCULATION
$\phi c=\left\{1-\exp(A\cdot P^{B})\right\}\cdot\left\{\beta \sqrt[m]{\ln(1-Pf)^{-1}}\right\}$

F I G. 1B

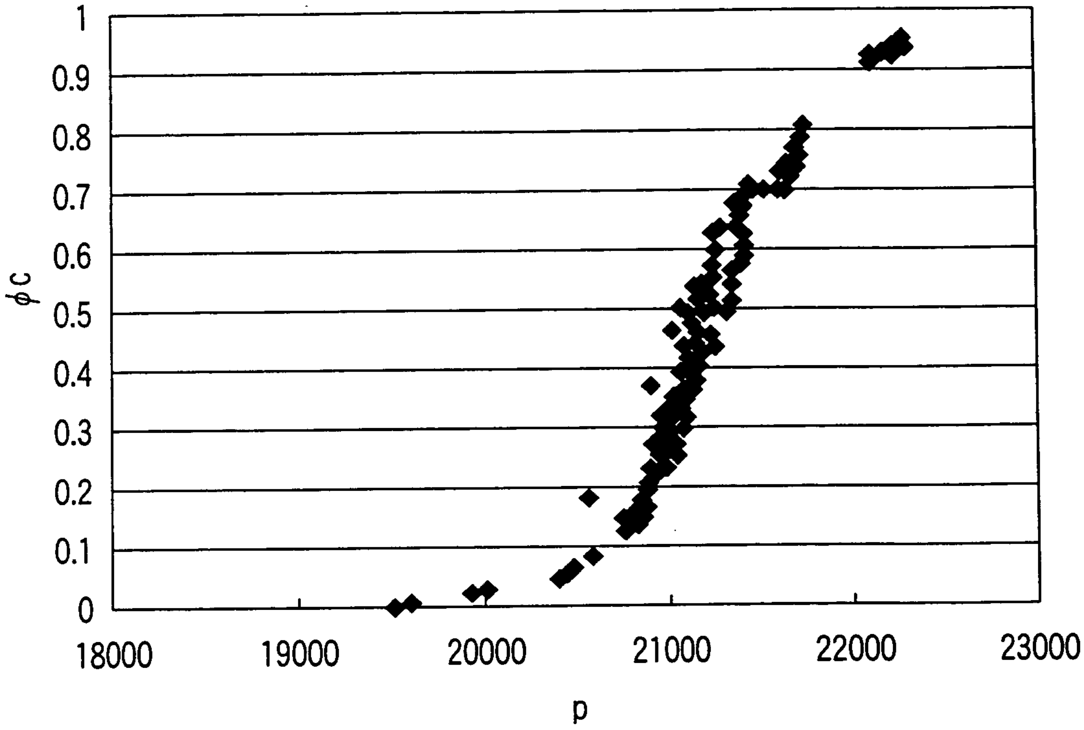

1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
ϕc
18000
19000
20000
21000
22000
23000
p

FIG. 2

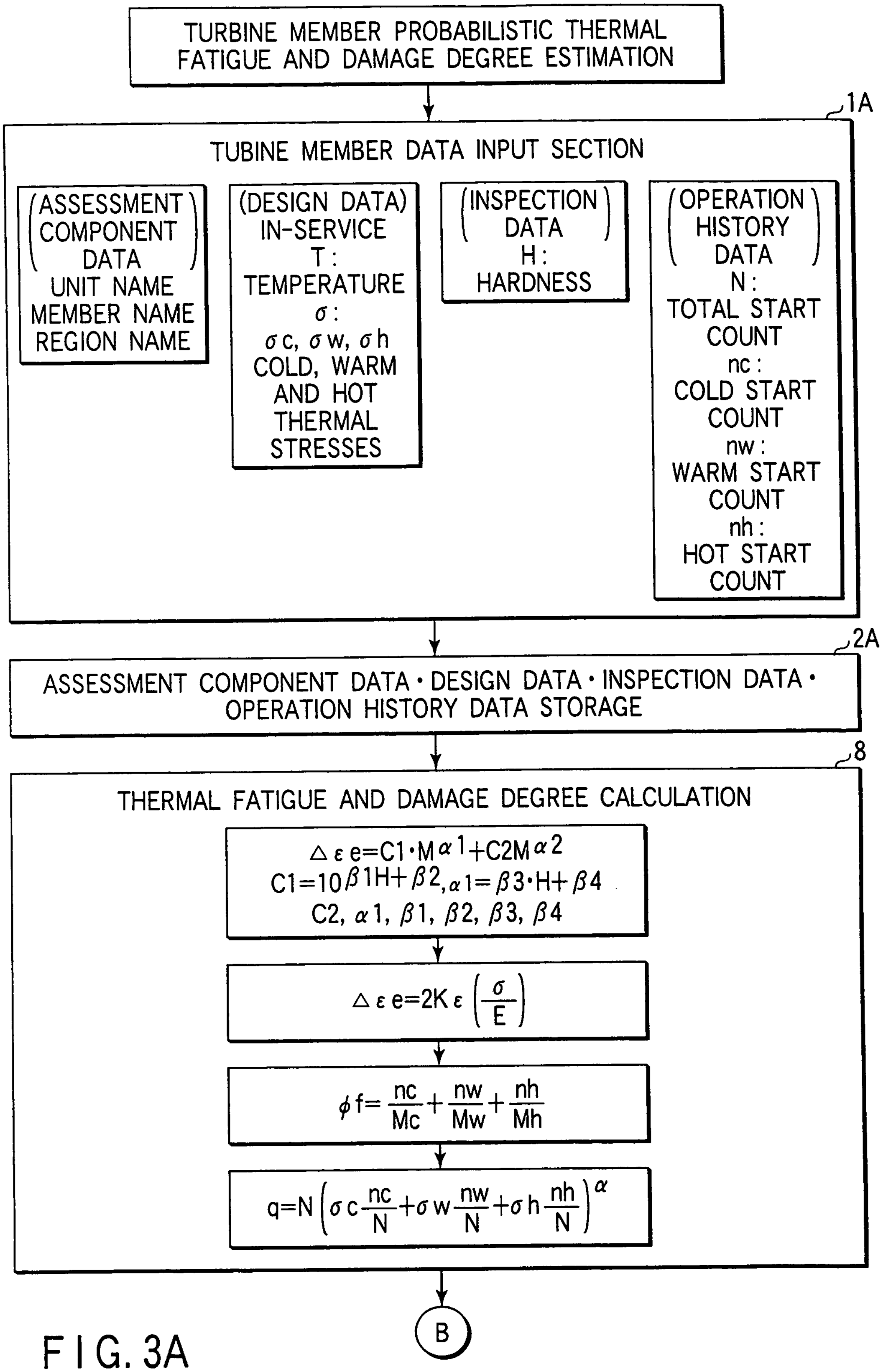

TURBINE MEMBER PROBABILISTIC THERMAL FATIGUE AND DAMAGE DEGREE ESTIMATION
1A
TUBINE MEMBER DATA INPUT SECTION
(ASSESSMENT COMPONENT DATA) UNIT NAME MEMBER NAME REGION NAME
(DESIGN DATA) IN-SERVICE T: TEMPERATURE σ: σc, σw, σh COLD, WARM AND HOT THERMAL STRESSES
(INSPECTION DATA) H: HARDNESS
(OPERATION HISTORY DATA) N: TOTAL START COUNT nc: COLD START COUNT nw: WARM START COUNT nh: HOT START COUNT
2A
ASSESSMENT COMPONENT DATA · DESIGN DATA · INSPECTION DATA · OPERATION HISTORY DATA STORAGE
8
THERMAL FATIGUE AND DAMAGE DEGREE CALCULATION
$\Delta\varepsilon e=C1\cdot M^{\alpha 1}+C2M^{\alpha 2}$
$C1=10^{\beta 1H+\beta 2}, \alpha 1=\beta 3\cdot H+\beta 4$
$C2, \alpha 1, \beta 1, \beta 2, \beta 3, \beta 4$
$\Delta\varepsilon e=2K\varepsilon\left(\frac{\sigma}{E}\right)$
$\phi f=\frac{nc}{Mc}+\frac{nw}{Mw}+\frac{nh}{Mh}$
$q=N\left(\sigma c\frac{nc}{N}+\sigma w\frac{nw}{N}+\sigma h\frac{nh}{N}\right)^{\alpha}$
B

FIG. 3A

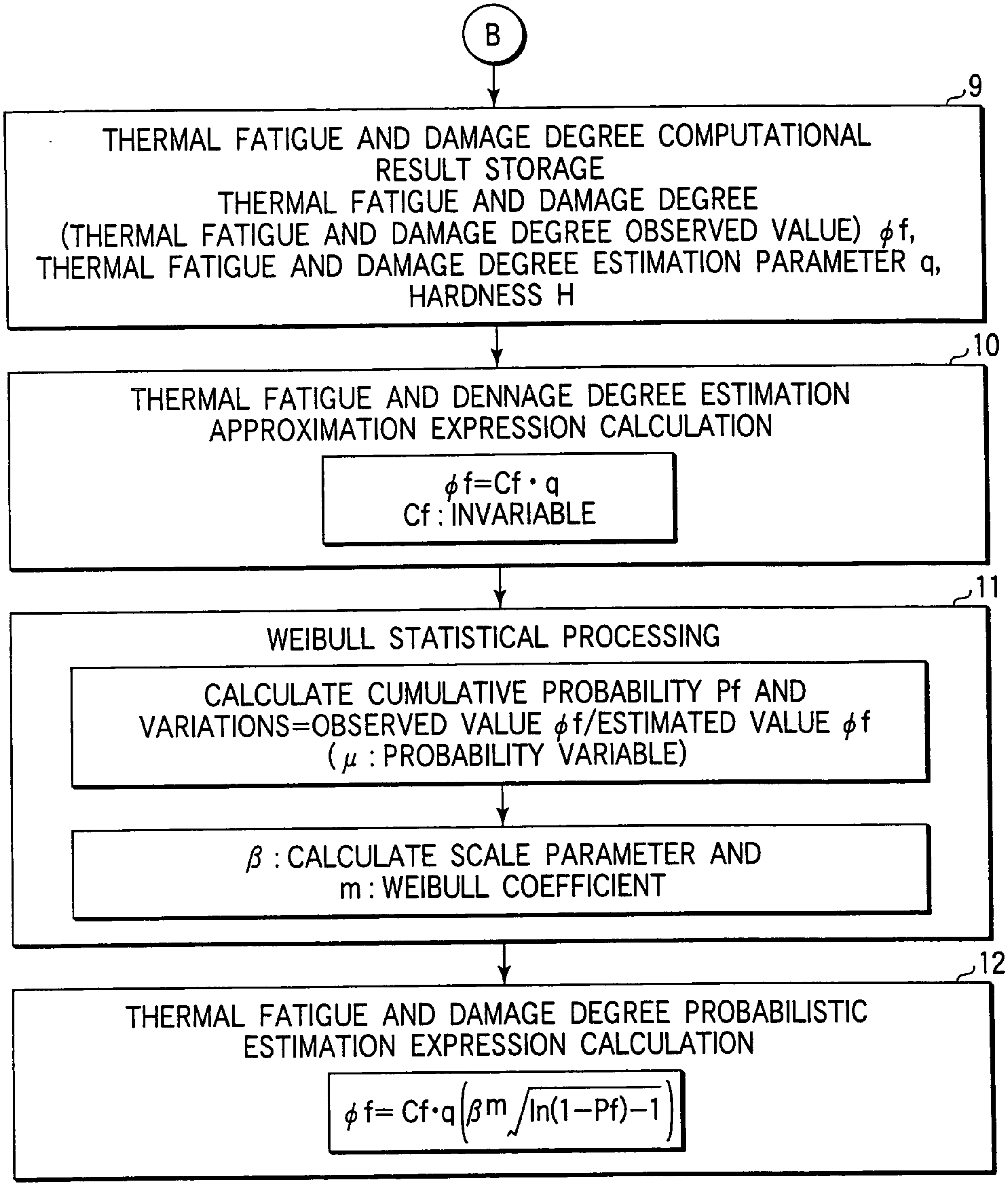

B
9
THERMAL FATIGUE AND DAMAGE DEGREE COMPUTATIONAL RESULT STORAGE
THERMAL FATIGUE AND DAMAGE DEGREE
(THERMAL FATIGUE AND DAMAGE DEGREE OBSERVED VALUE) ϕf,
THERMAL FATIGUE AND DAMAGE DEGREE ESTIMATION PARAMETER q,
HARDNESS H
10
THERMAL FATIGUE AND DENNAGE DEGREE ESTIMATION APPROXIMATION EXPRESSION CALCULATION
$\phi f=Cf\cdot q$
Cf : INVARIABLE
11
WEIBULL STATISTICAL PROCESSING
CALCULATE CUMULATIVE PROBABILITY Pf AND VARIATIONS=OBSERVED VALUE ϕf/ESTIMATED VALUE ϕf
(μ : PROBABILITY VARIABLE)
β : CALCULATE SCALE PARAMETER AND
m : WEIBULL COEFFICIENT
12
THERMAL FATIGUE AND DAMAGE DEGREE PROBABILISTIC ESTIMATION EXPRESSION CALCULATION
$\phi f= Cf\cdot q\left(\beta \sqrt[m]{\ln(1-Pf)-1}\right)$

FIG. 3B

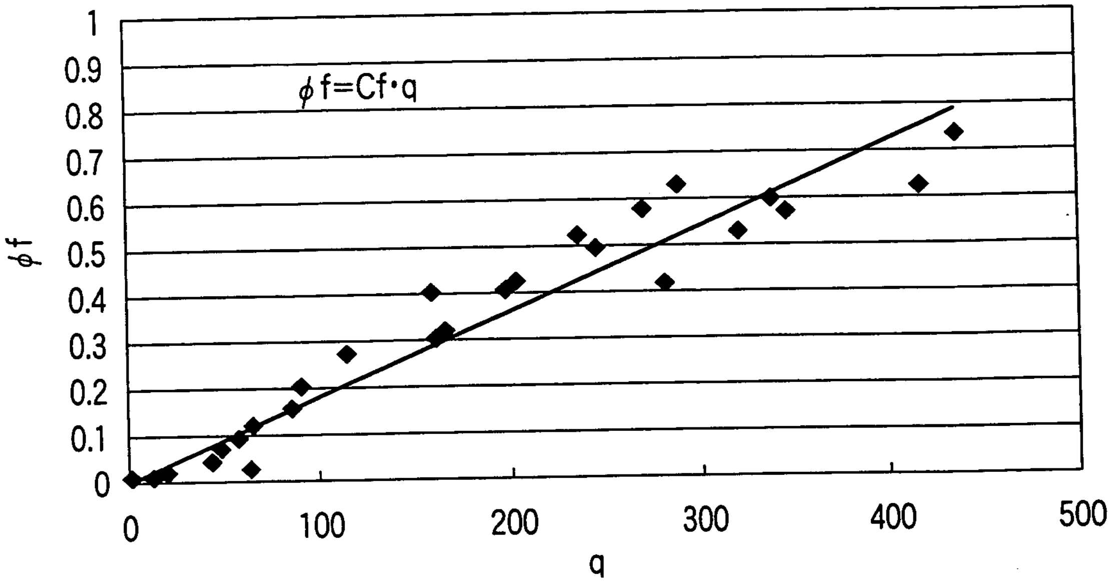


FIG.4

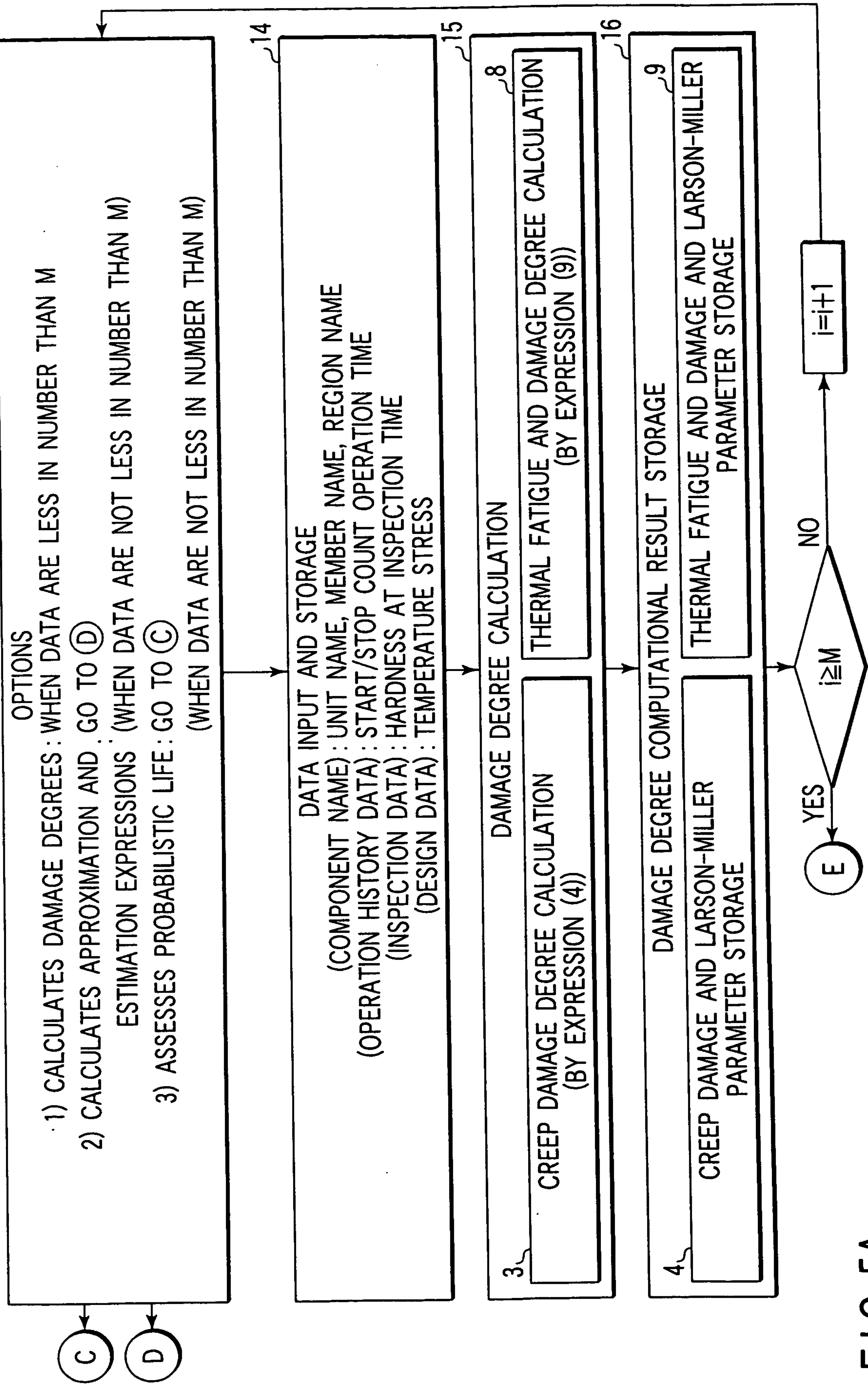

13
OPTIONS
1) CALCULATES DAMAGE DEGREES : WHEN DATA ARE LESS IN NUMBER THAN M
2) CALCULATES APPROXIMATION AND ESTIMATION EXPRESSIONS : GO TO D (WHEN DATA ARE NOT LESS IN NUMBER THAN M)
3) ASSESSES PROBABILISTIC LIFE : GO TO C (WHEN DATA ARE NOT LESS IN NUMBER THAN M)
C
D
14
DATA INPUT AND STORAGE
(COMPONENT NAME) : UNIT NAME, MEMBER NAME, REGION NAME
(OPERATION HISTORY DATA) : START/STOP COUNT OPERATION TIME
(INSPECTION DATA) : HARDNESS AT INSPECTION TIME
(DESIGN DATA) : TEMPERATURE STRESS
15
DAMAGE DEGREE CALCULATION
3
CREEP DAMAGE DEGREE CALCULATION (BY EXPRESSION (4))
8
THERMAL FATIGUE AND DAMAGE DEGREE CALCULATION (BY EXPRESSION (9))
16
DAMAGE DEGREE COMPUTATIONAL RESULT STORAGE
4
CREEP DAMAGE AND LARSON-MILLER PARAMETER STORAGE
9
THERMAL FATIGUE AND DAMAGE AND LARSON-MILLER PARAMETER STORAGE
i≧M
YES
NO
E
i=i+1

FIG. 5A

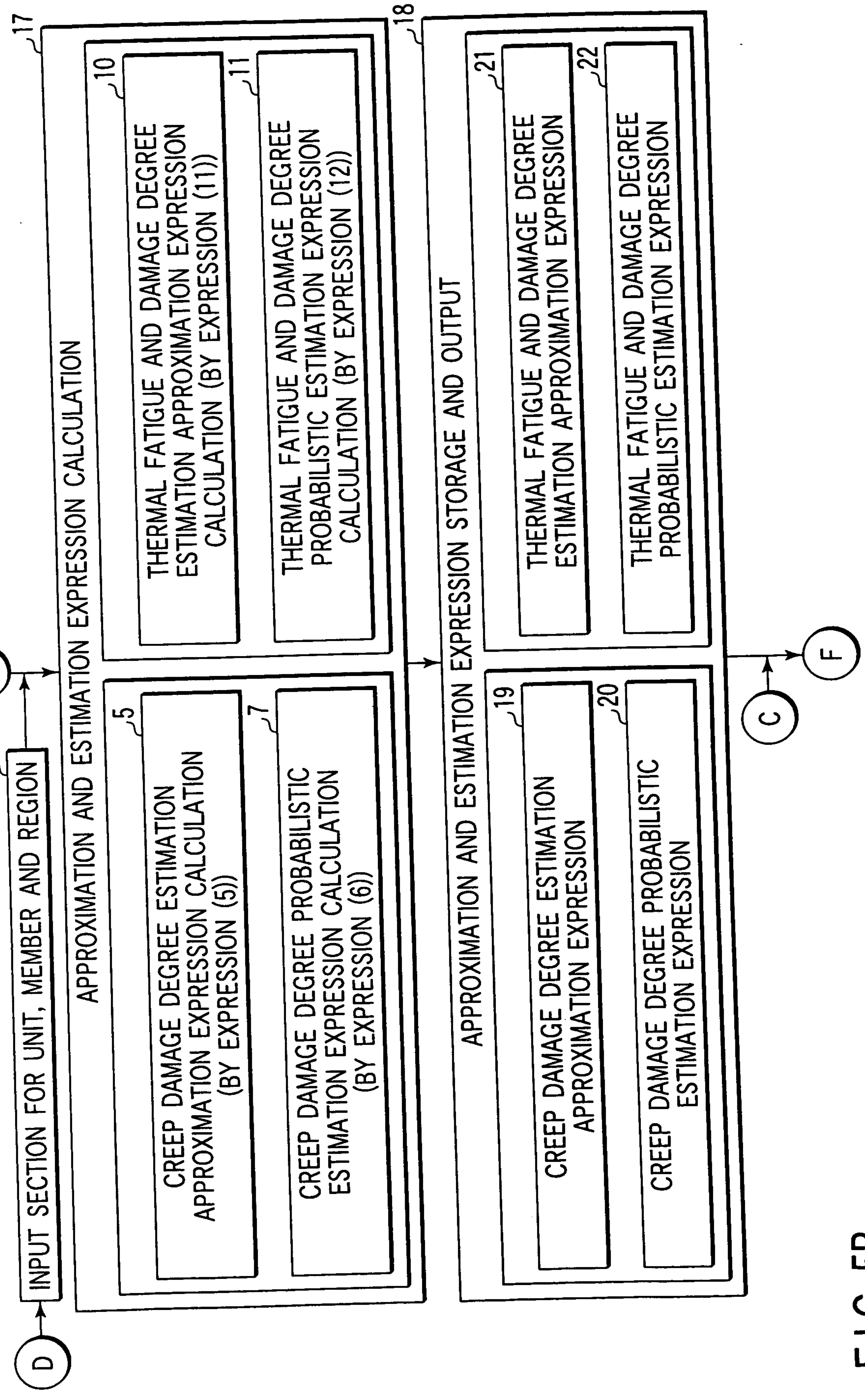

D
1B
INPUT SECTION FOR UNIT, MEMBER AND REGION
E
17
APPROXIMATION AND ESTIMATION EXPRESSION CALCULATION
5
CREEP DAMAGE DEGREE ESTIMATION APPROXIMATION EXPRESSION CALCULATION (BY EXPRESSION (5))
7
CREEP DAMAGE DEGREE PROBABILISTIC ESTIMATION EXPRESSION CALCULATION (BY EXPRESSION (6))
10
THERMAL FATIGUE AND DAMAGE DEGREE ESTIMATION APPROXIMATION EXPRESSION CALCULATION (BY EXPRESSION (11))
11
THERMAL FATIGUE AND DAMAGE DEGREE PROBABILISTIC ESTIMATION EXPRESSION CALCULATION (BY EXPRESSION (12))
18
APPROXIMATION AND ESTIMATION EXPRESSION STORAGE AND OUTPUT
19
CREEP DAMAGE DEGREE ESTIMATION APPROXIMATION EXPRESSION
20
CREEP DAMAGE DEGREE PROBABILISTIC ESTIMATION EXPRESSION
21
THERMAL FATIGUE AND DAMAGE DEGREE ESTIMATION APPROXIMATION EXPRESSION
22
THERMAL FATIGUE AND DAMAGE DEGREE PROBABILISTIC ESTIMATION EXPRESSION
C
F

FIG. 5B

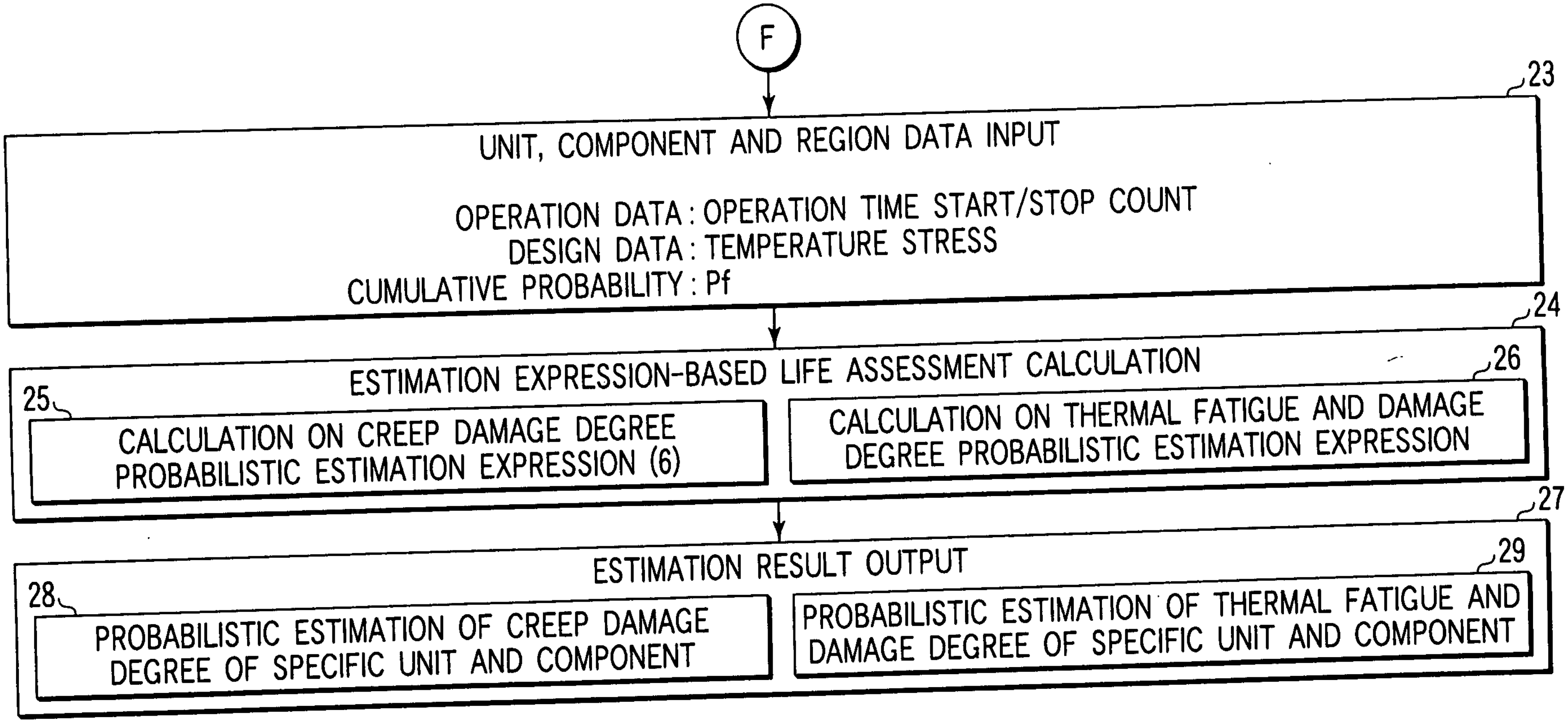

F
UNIT, COMPONENT AND REGION DATA INPUT
OPERATION DATA : OPERATION TIME START/STOP COUNT
DESIGN DATA : TEMPERATURE STRESS
CUMULATIVE PROBABILITY : Pf
23
ESTIMATION EXPRESSION-BASED LIFE ASSESSMENT CALCULATION
24
25
CALCULATION ON CREEP DAMAGE DEGREE PROBABILISTIC ESTIMATION EXPRESSION (6)
26
CALCULATION ON THERMAL FATIGUE AND DAMAGE DEGREE PROBABILISTIC ESTIMATION EXPRESSION
ESTIMATION RESULT OUTPUT
27
28
PROBABILISTIC ESTIMATION OF CREEP DAMAGE DEGREE OF SPECIFIC UNIT AND COMPONENT
29
PROBABILISTIC ESTIMATION OF THERMAL FATIGUE AND DAMAGE DEGREE OF SPECIFIC UNIT AND COMPONENT

FIG. 5C

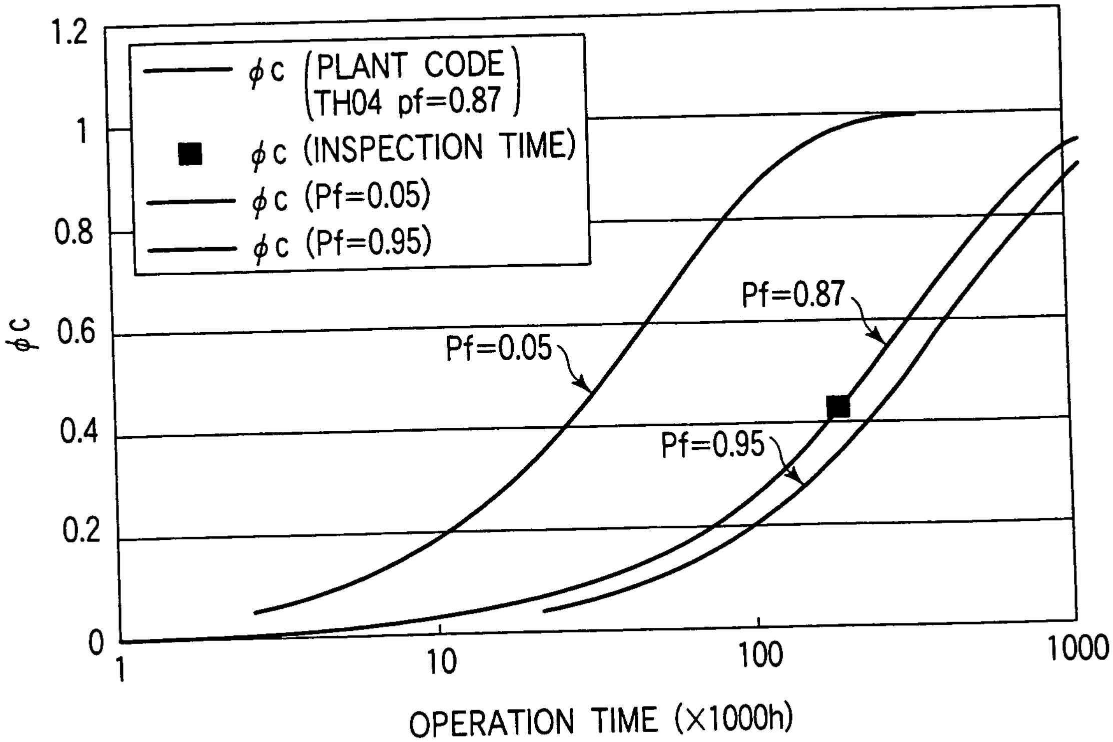

ϕc (PLANT CODE TH04 pf=0.87)
ϕc (INSPECTION TIME)
ϕc (Pf=0.05)
ϕc (Pf=0.95)
1.2
1
0.8
0.6
0.4
0.2
0
ϕc
Pf=0.87
Pf=0.05
Pf=0.95
1
10
100
1000
OPERATION TIME (×1000h)

FIG. 6

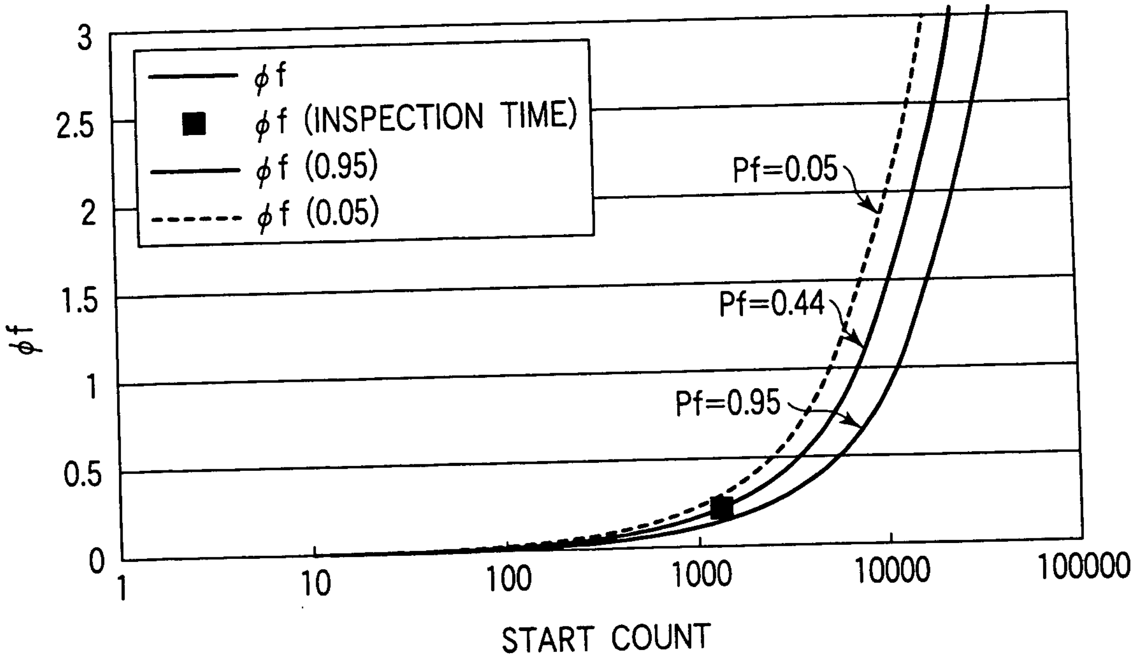

ϕf
ϕf (INSPECTION TIME)
ϕf (0.95)
ϕf (0.05)
3
2.5
2
1.5
1
0.5
0
ϕf
Pf=0.05
Pf=0.44
Pf=0.95
1
10
100
1000
10000
100000
START COUNT

FIG. 7

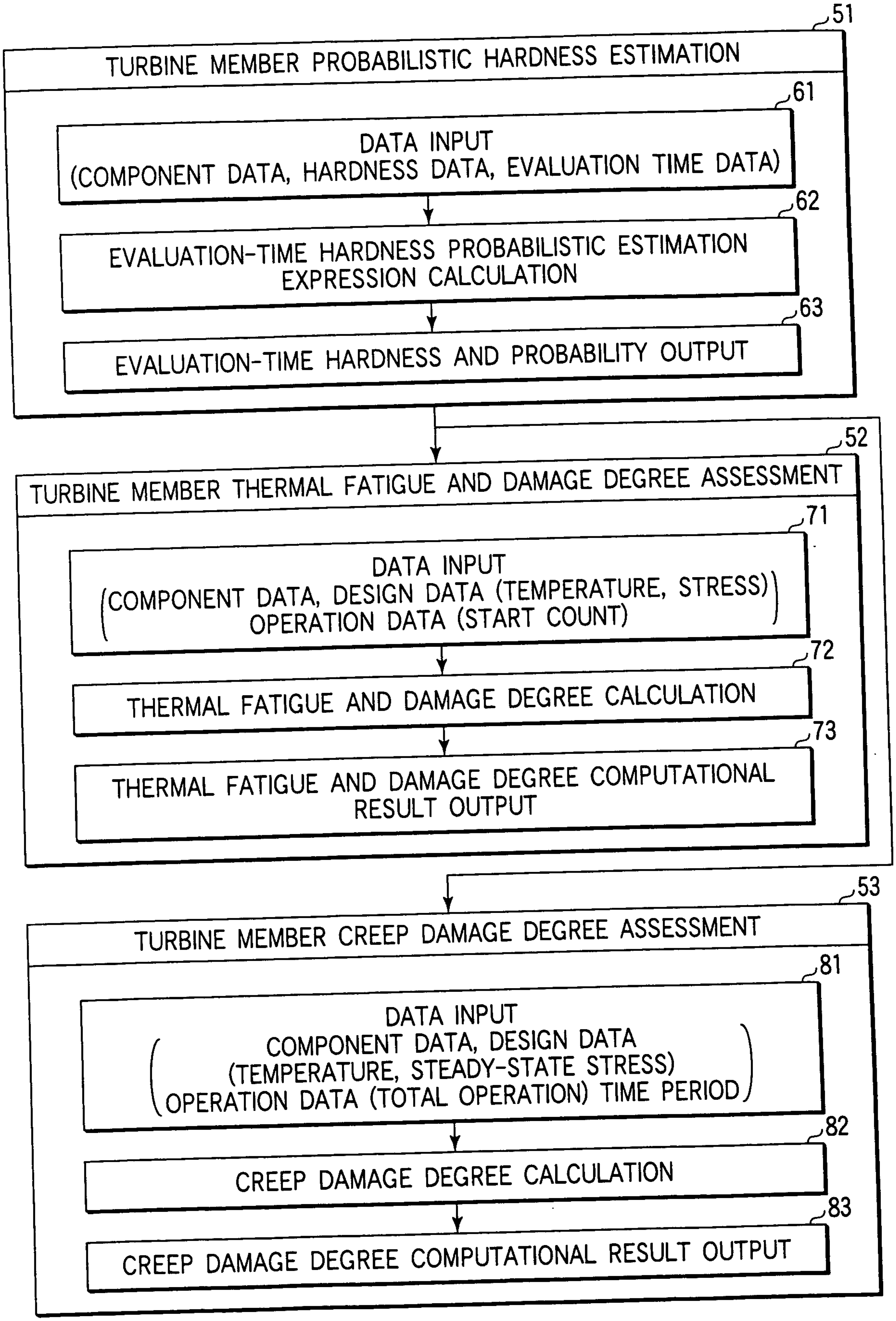

51
TURBINE MEMBER PROBABILISTIC HARDNESS ESTIMATION
61
DATA INPUT (COMPONENT DATA, HARDNESS DATA, EVALUATION TIME DATA)
62
EVALUATION-TIME HARDNESS PROBABILISTIC ESTIMATION EXPRESSION CALCULATION
63
EVALUATION-TIME HARDNESS AND PROBABILITY OUTPUT
52
TURBINE MEMBER THERMAL FATIGUE AND DAMAGE DEGREE ASSESSMENT
71
DATA INPUT (COMPONENT DATA, DESIGN DATA (TEMPERATURE, STRESS) OPERATION DATA (START COUNT))
72
THERMAL FATIGUE AND DAMAGE DEGREE CALCULATION
73
THERMAL FATIGUE AND DAMAGE DEGREE COMPUTATIONAL RESULT OUTPUT
53
TURBINE MEMBER CREEP DAMAGE DEGREE ASSESSMENT
81
DATA INPUT (COMPONENT DATA, DESIGN DATA (TEMPERATURE, STEADY-STATE STRESS) OPERATION DATA (TOTAL OPERATION) TIME PERIOD)
82
CREEP DAMAGE DEGREE CALCULATION
83
CREEP DAMAGE DEGREE COMPUTATIONAL RESULT OUTPUT

FIG. 8

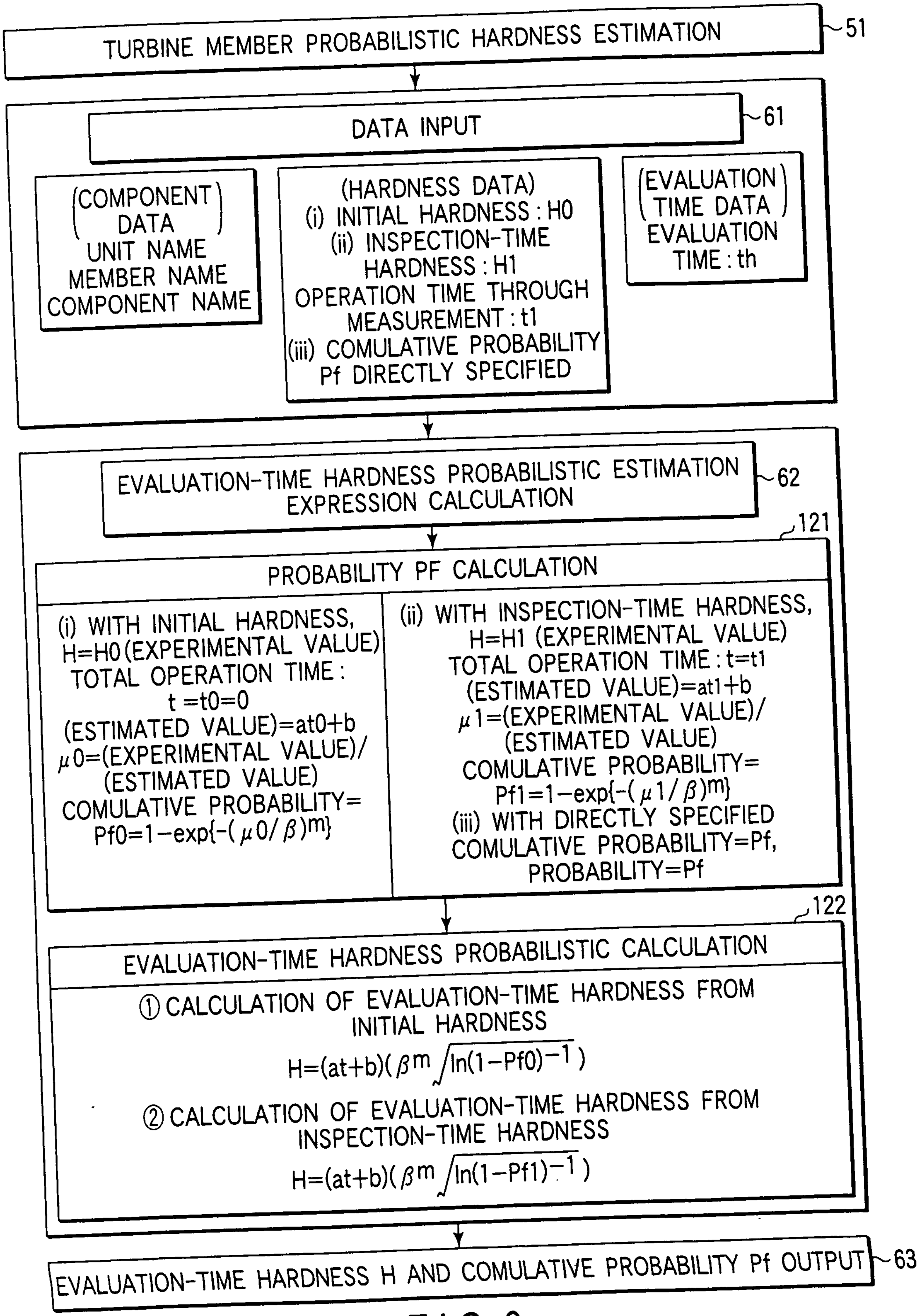

TURBINE MEMBER PROBABILISTIC HARDNESS ESTIMATION
51
DATA INPUT
61
(COMPONENT DATA) UNIT NAME MEMBER NAME COMPONENT NAME
(HARDNESS DATA) (i) INITIAL HARDNESS : H0 (ii) INSPECTION-TIME HARDNESS : H1 OPERATION TIME THROUGH MEASUREMENT : t1 (iii) COMULATIVE PROBABILITY Pf DIRECTLY SPECIFIED
(EVALUATION TIME DATA) EVALUATION TIME : th
EVALUATION-TIME HARDNESS PROBABILISTIC ESTIMATION EXPRESSION CALCULATION
62
121
PROBABILITY PF CALCULATION
(i) WITH INITIAL HARDNESS, H=H0 (EXPERIMENTAL VALUE) TOTAL OPERATION TIME : t =t0=0 (ESTIMATED VALUE)=at0+b μ0=(EXPERIMENTAL VALUE)/(ESTIMATED VALUE) COMULATIVE PROBABILITY= Pf0=1−exp{−(μ0/β)m}
(ii) WITH INSPECTION-TIME HARDNESS, H=H1 (EXPERIMENTAL VALUE) TOTAL OPERATION TIME : t=t1 (ESTIMATED VALUE)=at1+b μ1=(EXPERIMENTAL VALUE)/(ESTIMATED VALUE) COMULATIVE PROBABILITY= Pf1=1−exp{−(μ1/β)m}
(iii) WITH DIRECTLY SPECIFIED COMULATIVE PROBABILITY=Pf, PROBABILITY=Pf
122
EVALUATION-TIME HARDNESS PROBABILISTIC CALCULATION
① CALCULATION OF EVALUATION-TIME HARDNESS FROM INITIAL HARDNESS
H=(at+b)(β m√ln(1−Pf0)−1)
② CALCULATION OF EVALUATION-TIME HARDNESS FROM INSPECTION-TIME HARDNESS
H=(at+b)(β m√ln(1−Pf1)−1)
EVALUATION-TIME HARDNESS H AND COMULATIVE PROBABILITY Pf OUTPUT
63

FIG. 9

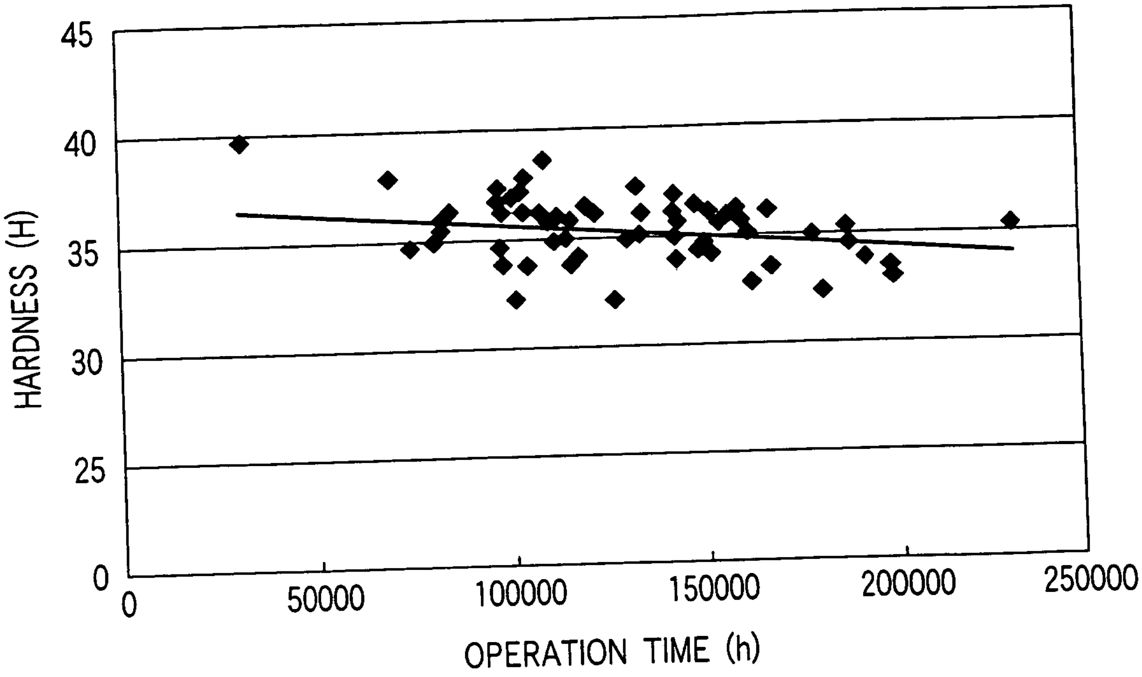

45
40
35
30
25
0
HARDNESS (H)
0
50000
100000
150000
200000
250000
OPERATION TIME (h)

FIG. 10

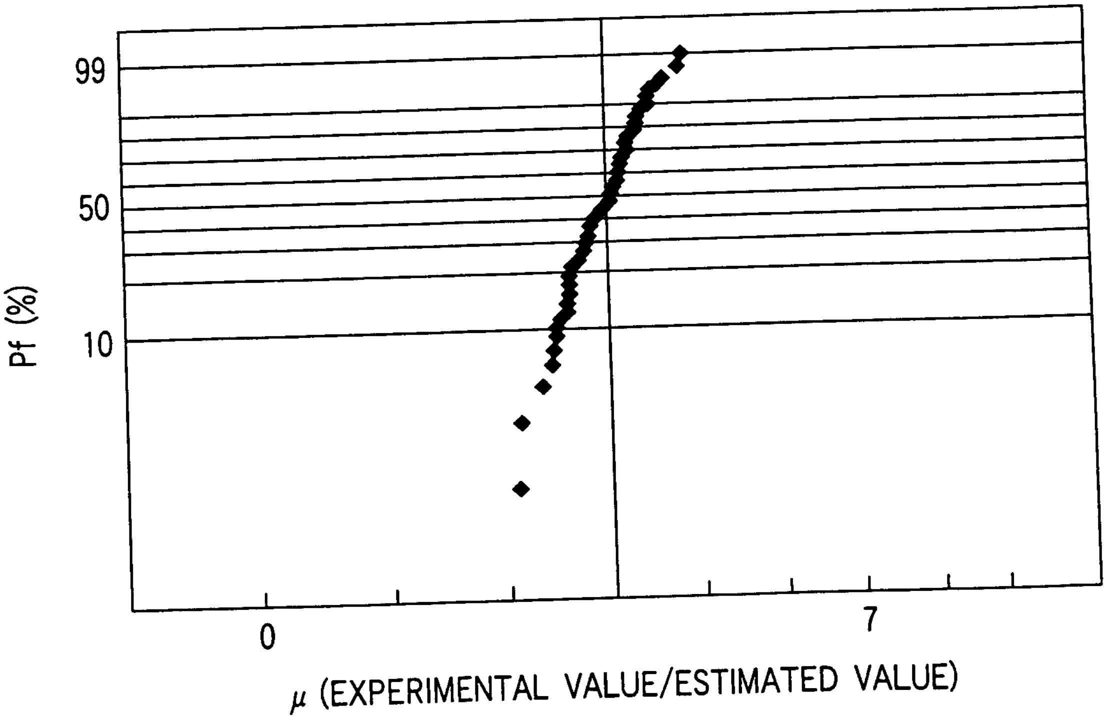

99
50
10
Pf (%)
0
7
μ (EXPERIMENTAL VALUE/ESTIMATED VALUE)

FIG. 11

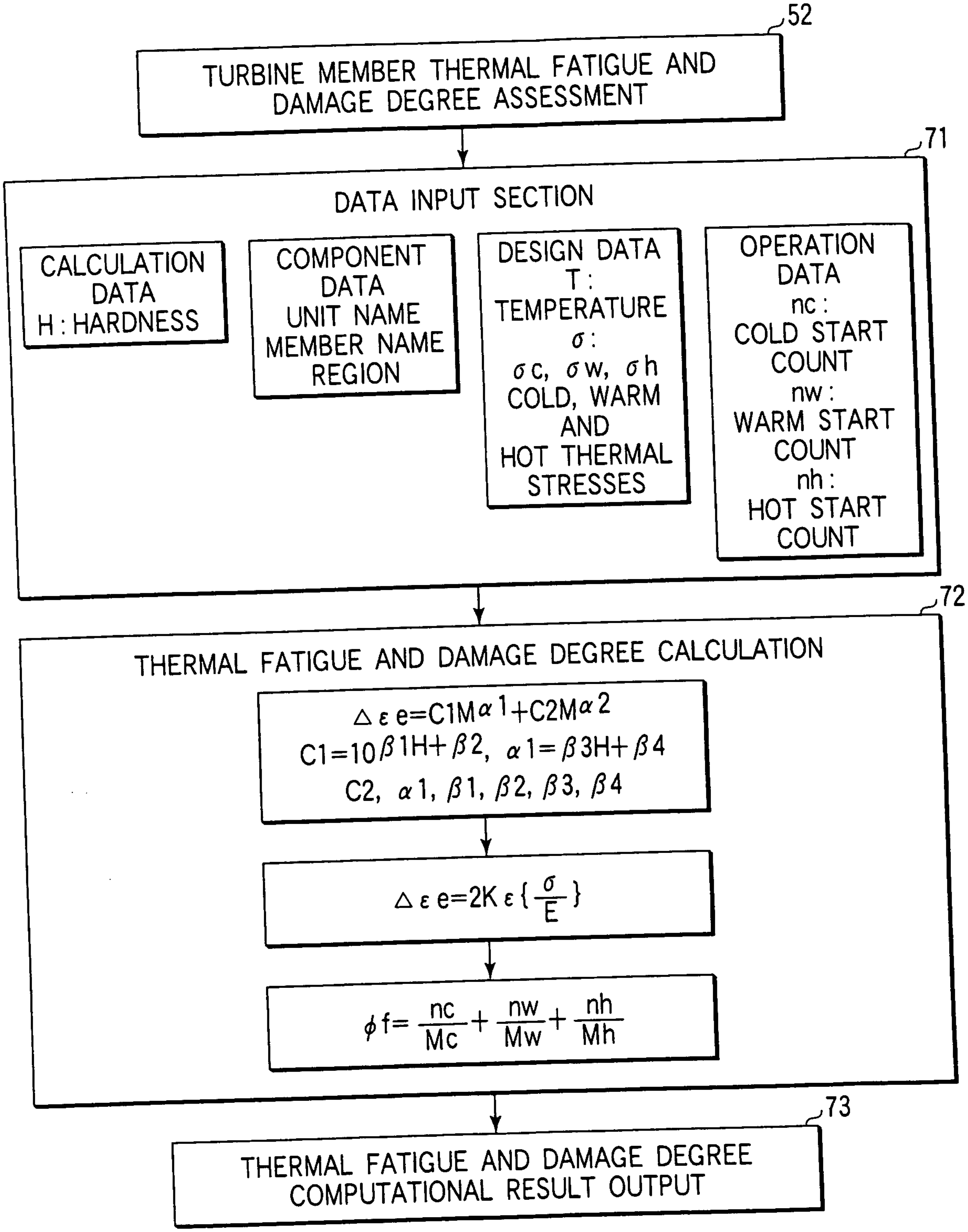

52
TURBINE MEMBER THERMAL FATIGUE AND DAMAGE DEGREE ASSESSMENT
71
DATA INPUT SECTION
CALCULATION DATA
H : HARDNESS
COMPONENT DATA
UNIT NAME
MEMBER NAME
REGION
DESIGN DATA
T : TEMPERATURE
σ :
σc, σw, σh
COLD, WARM AND HOT THERMAL STRESSES
OPERATION DATA
nc : COLD START COUNT
nw : WARM START COUNT
nh : HOT START COUNT
72
THERMAL FATIGUE AND DAMAGE DEGREE CALCULATION
$\Delta\varepsilon e = C1M^{\alpha 1} + C2M^{\alpha 2}$
$C1 = 10^{\beta 1H + \beta 2}$, $\alpha 1 = \beta 3H + \beta 4$
C2, $\alpha 1$, $\beta 1$, $\beta 2$, $\beta 3$, $\beta 4$
$\Delta\varepsilon e = 2K\varepsilon\{\frac{\sigma}{E}\}$
$\phi f = \frac{nc}{Mc} + \frac{nw}{Mw} + \frac{nh}{Mh}$
73
THERMAL FATIGUE AND DAMAGE DEGREE COMPUTATIONAL RESULT OUTPUT

FIG. 12

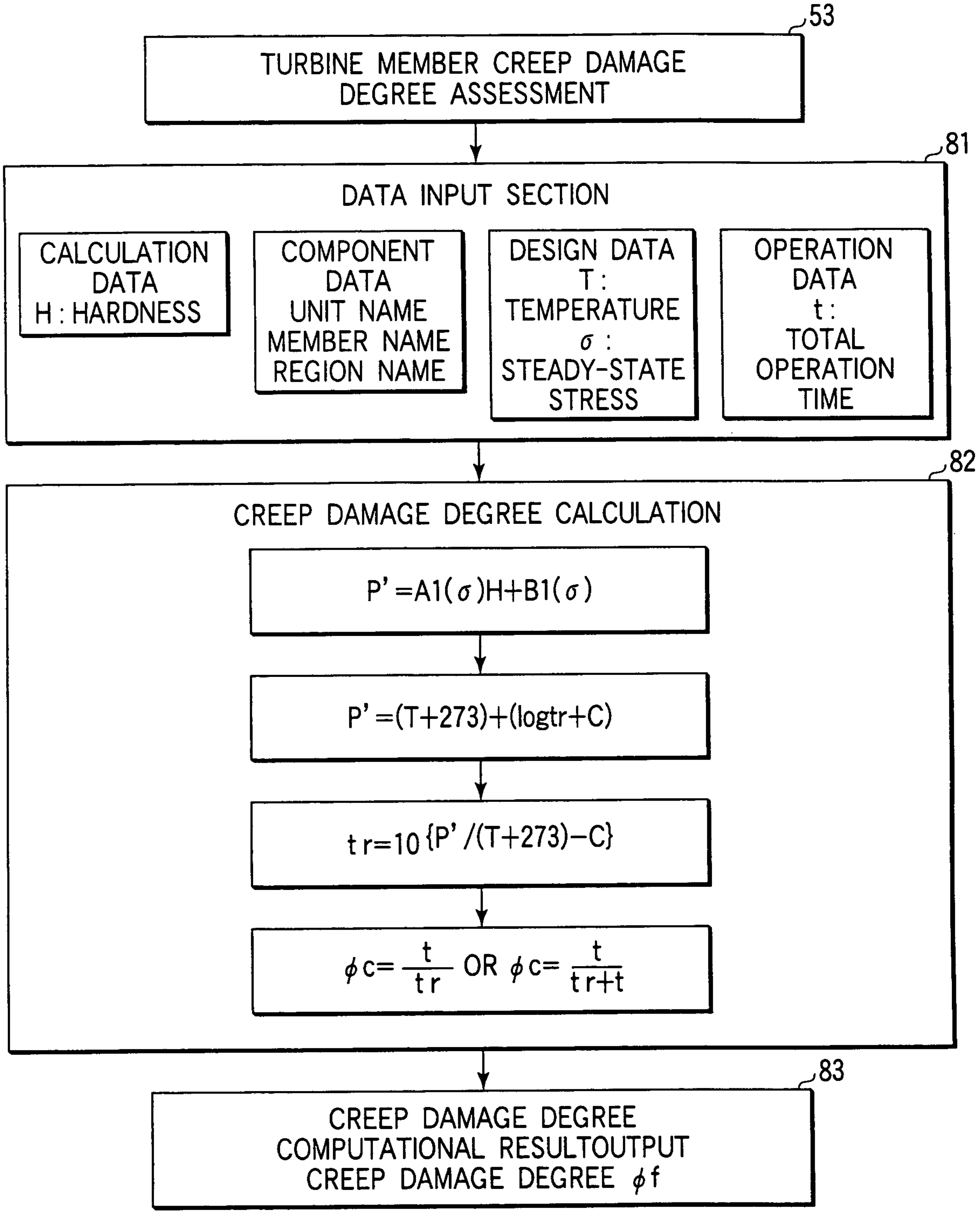

53
TURBINE MEMBER CREEP DAMAGE DEGREE ASSESSMENT
81
DATA INPUT SECTION
CALCULATION DATA H : HARDNESS
COMPONENT DATA UNIT NAME MEMBER NAME REGION NAME
DESIGN DATA T : TEMPERATURE σ : STEADY-STATE STRESS
OPERATION DATA t : TOTAL OPERATION TIME
82
CREEP DAMAGE DEGREE CALCULATION
P' =A1(σ)H+B1(σ)
P' =(T+273)+(logtr+C)
tr=10{P' /(T+273)−C}
φc= t/tr OR φc= t/(tr+t)
83
CREEP DAMAGE DEGREE COMPUTATIONAL RESULTOUTPUT CREEP DAMAGE DEGREE φf

FIG. 13

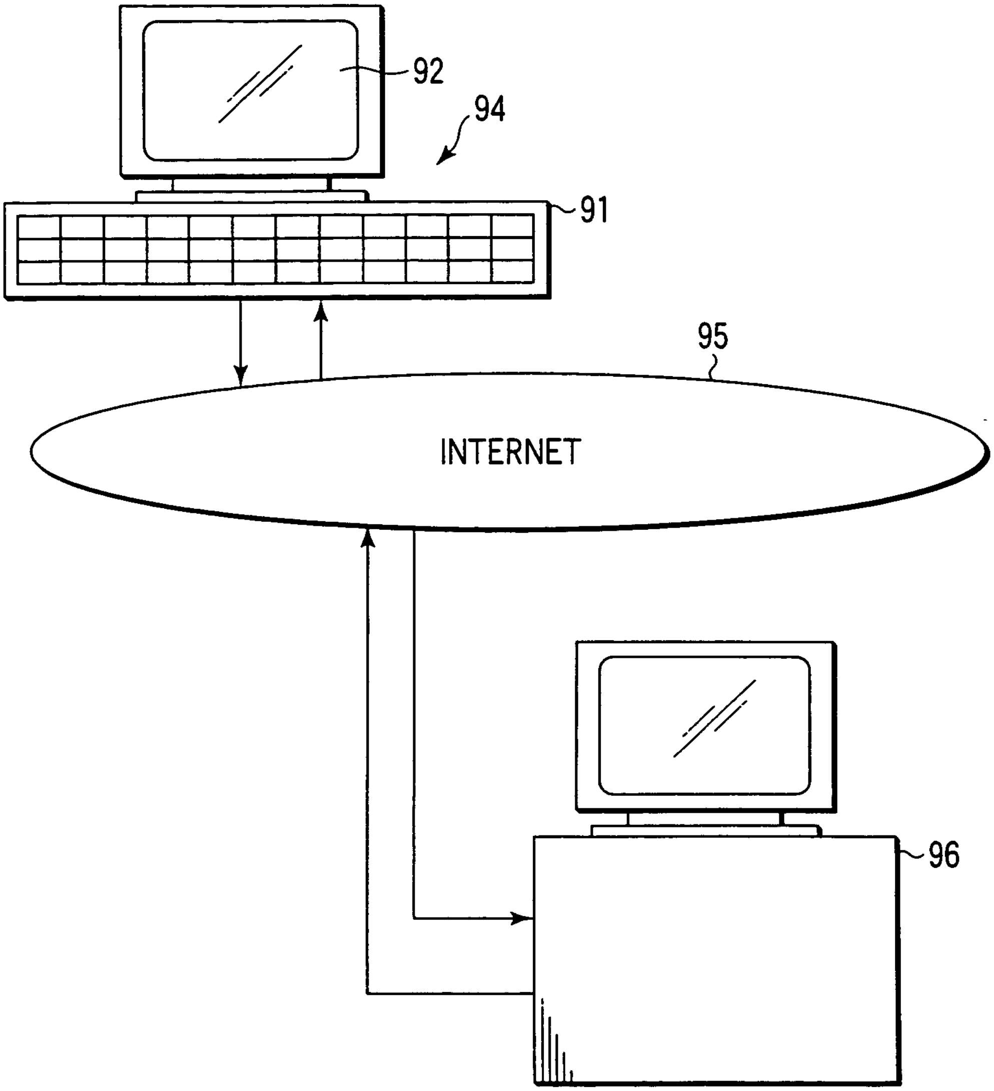


FIG. 14